

CLAIMS:

What is claimed is:

1. A passive direct organic fuel cell comprising:
an anode;
5 an anode enclosure communicating with said anode and containing an organic fuel solution;
a cathode communicating with an oxygen source;
an electrolyte sandwiched between said anode and said cathode; and,
wherein said anode, said cathode, and said electrolyte are operative to
10 oxidize said organic fuel solution at said anode and reduce oxygen at said cathode to generate power having a power density of at least 15 mW/cm² when operating at room temperature.
2. A passive direct organic fuel cell as defined by claim 1 wherein said fuel solution contains at least 4.4 M formic acid.
3. A passive direct organic fuel cell as defined by claim 1 wherein said cathode communicates with air, and wherein oxygen is supplied to said cathode for reaction with said formic acid fuel solution from the air.
4. A passive direct organic fuel cell as defined by claim 1 wherein said anode enclosure has a gas remover configured to allow passage of CO₂ from said enclosure while substantially preventing passage of said organic fuel solution, said gas remover positioned to promote circulation of said organic
5 fuel solution as gas travels therethrough.
5. A passive direct organic fuel cell as defined by claim 4 wherein said anode enclosure includes a wall, and wherein said gas remover comprises a plurality of generally tubular passages through said wall having a diameter of
5 less than 1/32", a length to diameter ratio of at least 0.5, and wherein said

plurality of passages are provided in a ratio of at least 20 per cm² of active anode area.

6. A passive direct organic fuel cell as defined by claim 4 wherein
10 said anode enclosure includes a wall, said anode is generally planar, and
wherein said gas remover comprises a plurality of generally tubular passages
through said wall, said passages spaced from the plane of said anode by at least
0.01”.

7. A passive direct organic fuel cell as defined by claim 1 and
further including an anode current collector overlying said anode, a conducting
sheet sandwiched between said anode and said anode current collector.

8. A passive direct organic fuel cell as defined by claim 7 wherein
said conducting sheet comprises one or both of a gold mesh or a modified
carbon cloth, said modified carbon cloth having a modified surface that results
5 in a contact angle with water of less than 120°.

9. A passive direct organic fuel cell as defined by claim 7 and
further including a layer on said anode current collector, said layer being
resistive to formic acid and at least 0.1 micron thick.

10. A passive direct organic fuel cell as defined by claim 9 wherein
said layer contains one or more of gold or silver and has a thickness between 1
and 5 microns.

11. A passive direct organic fuel cell as defined by claim 1 wherein
said electrolyte comprises a solid polymer electrolyte that is substantially
impervious to said organic fuel solution.

12. A passive direct organic fuel cell as defined by claim 1 wherein said anode includes a catalyst layer containing less than 25% (wt) of a binder made of a copolymer of tetrafluoroethylene and perfluorovinylether sulfonic acid.

13. A passive direct organic fuel cell as defined by claim 1 wherein said anode includes a catalyst layer containing a PTFE binder.

14. A passive direct organic fuel cell as defined by claim 1 wherein a polymer sealant is adjacent to said anode enclosure, said polymer sealant holding said anode enclosure in place on the fuel cell and sealing said anode enclosure against leakage of said organic fuel solution, said polymer sealant being one or more of a silicone or an epoxy.

15. A passive direct organic fuel cell as defined by claim 1 and further including a replaceable fuel cartridge, said anode enclosure having a loading passage for connecting with said replaceable fuel cartridge, said loading passage communicating with said chamber.

16. A passive direct organic fuel cell as defined by claim 15 wherein said loading passage comprises a fill tube extending from said anode enclosure and has a valve, and wherein said replaceable fuel cartridge has a recessed valve for cooperating with said fill tube.

17. A passive direct organic fuel cell comprising:
an anode;
an anode enclosure communicating with said anode and containing an organic fuel solution that is at least 1.8 M formic acid;
a cathode communicating with an oxygen source;
a solid polymer electrolyte sandwiched between said anode and said cathode that is substantially impervious to said organic fuel solution; and,

wherein said anode, said cathode, and said electrolyte are operative to
10 generate power having a power density of at least 10 mW/cm² when operating
at room temperature.

18. A passive direct organic fuel cell as defined by claim 17 wherein
said fuel solution is at least 4.4 M formic acid and said power density is at least
14 mW/cm².

19. A passive direct organic fuel cell as defined by claim 17 wherein
said fuel solution is at least 8.8 M, and wherein said anode, said cathode, and
said electrolyte are operative to generate a power density of at least 10 mW/cm²
5 at a constant voltage of 0.26 V when operating at room temperature for a
period of at least 3 hours with no more than 0.6 cc of said fuel solution.

20. A passive direct organic fuel cell as defined by claim 17 wherein
said anode enclosure has a gas remover configured to allow passage of CO₂
from said enclosure while substantially preventing passage of said organic fuel
5 solution, said gas remover positioned to promote circulation of said organic
fuel solution as gas travels therethrough.

21. A passive direct organic fuel cell as defined by claim 17 wherein
said anode enclosure, said anode and said electrolyte are held together by a
polymer sealant that is resistive to formic acid.

22. A passive direct organic fuel cell as defined by claim 17 wherein
said anode enclosure includes a fill passage for connection to a replaceable fuel
cartridge.

23. A passive direct organic fuel cell as defined by claim 17 and
further including a replaceable fuel cartridge made of a PTFE and containing a

liquid organic fuel solution, said replaceable fuel cartridge having a recessed
5 valve.

24. A direct organic fuel cell comprising:
an anode enclosure having a chamber, a liquid organic fuel solution
contained in said chamber;
5 an anode communicating with said chamber;
a cathode electrically connected to said anode;
an electrolyte sandwiched between said anode and said cathode; and,
said anode enclosure configured to promote circulation of said liquid
organic fuel solution through movement of gas through said organic fuel
10 solution.

25. A direct organic fuel cell as defined by claim 24 and wherein said
anode enclosure includes a gas remover configured to selectively allow passage
of gas from said anode chamber while preventing passage of said liquid fuel
5 solution.

26. A direct organic fuel cell as defined by claim 25 wherein said
anode enclosure includes a wall, and wherein said gas remover comprises a
plurality of passages through said wall and communicating with said chamber.

27. A direct organic fuel cell as defined by claim 26 wherein each of
said plurality of passages is tubular and has an inside diameter of less than
1/32".

28. A direct organic fuel cell as defined by claim 26 wherein each of
said plurality of passages has an inside width of less than 0.01".

29. A direct organic fuel cell as defined by claim 26 wherein said plurality of passages are provided in a ratio of at least 20 passages per cm² of useful anode surface area.

30. A direct organic fuel cell as defined by claim 26 wherein said plurality of passages include at least 100 passages.

31. A direct organic fuel cell as defined by claim 26 wherein each of said plurality of passages has a hydrophobic interior surface.

32. A direct organic fuel cell as defined by claim 26 wherein each of said passages has a length to width ratio of at least 0.5.

33. A direct organic fuel cell as defined by claim 26 wherein said anode enclosure includes an interior surface, and wherein each of said passages extends beyond said interior surface by a distance of at least 0.01”.

34. A direct organic fuel cell as defined by claim 25 wherein said anode is generally planar, and wherein said gas remover is spaced from the plane of said anode by a distance of at least 0.01 in.

35. A direct organic fuel cell as defined by claim 25 wherein said anode enclosure has a loading passage, and wherein the direct organic fuel cell further includes a replaceable fuel cartridge having a fill port for cooperating
5 with said loading passage.

36. A method for making an organic fuel cell assembly comprising the steps of:

providing a membrane electrode assembly including a solid polymer
5 electrolyte sandwiched between an anode and a cathode;

hot pressing an anode current collector over said anode to define a first perimeter surface;

hot pressing a cathode current collector over said cathode to define a second perimeter surface;

10 sealing said first and second perimeter surfaces with at least one sealant;
and

attaching an anode enclosure to one of said membrane electrode assembly or said anode current collector using an adhesive that is resistive to formic acid.

37. A method for making an organic fuel cell assembly as defined by claim 36 and further including the step of providing a plurality of passages in said anode enclosure configured to selectively allow gas to exit said anode
5 enclosure while substantially preventing passage of an organic fuel solution.

38. A method for making an organic fuel cell assembly as defined by claim 36 wherein said solid polymer electrolyte has a glass transition temperature, and wherein the steps of hot pressing said cathode current
5 collector and said anode current collector to said membrane electrode assembly are carried out at a temperature greater than said solid polymer electrolyte glass transition temperature.

39. A method for making an organic fuel cell assembly as defined by claim 36 wherein said solid polymer electrolyte has a glass transition temperature, and further including the step of curing said membrane electrode
5 assembly with said hot pressed cathode current collector and said hot pressed anode current collector at a temperature below said glass transition temperature after the step of sealing said first and second perimeter surfaces.

40. A method for making an organic fuel cell assembly as defined by claim 36 wherein said sealant comprises one or more of an epoxy or a silicone.

41. A method for making an organic fuel cell assembly as defined by claim 36 wherein said sealant is resistant to formic acid.

42. A method for modifying a fuel cell carbon cloth comprising the steps of:

chemically modifying the surface of the carbon cloth to cause the
5 contact angle between water and the carbon cloth to be less than 120°.

43. A method for modifying fuel cell carbon cloth as defined by claim 42 wherein the step of chemically modifying the surface of the carbon cloth includes subjecting the carbon cloth to an oxygen plasma at less than
5 atmospheric pressure.

44. A method for modifying fuel cell carbon cloth as defined by claim 42 wherein the step of chemically modifying the surface of the carbon cloth includes modifying the surface of the carbon cloth to include CO and
5 COOH groups in an amount sufficient to cause the carbon cloth to support oxidation of at least 13 M formic acid fuel solution in the fuel cell.

45. A method for modifying fuel cell carbon cloth as defined by claim 42 wherein the step of chemically modifying the surface includes chemically modifying the surface to include hydrophilic ligands.
5

46. A method for modifying fuel cell carbon cloth as defined by claim 45 wherein said hydrophilic ligands include one or more of CO, OH, and COOH groups.

47. A method for modifying fuel cell carbon cloth as defined by claim 42 wherein the step of chemically modifying the surface includes

chemically modifying the surface to cause the contact angle between water and
5 the carbon cloth to be 0°.

48. A direct organic fuel cell comprising:
an anode;
10 an anode enclosure communicating with said anode and containing an
organic fuel solution;
a cathode communicating with an oxygen source;
an electrolyte sandwiched between said anode and said cathode; and,
carbon cloth on one or both of said anode and said cathode, said carbon
15 cloth having a modified surface that results in a contact angle of less than 120°
with water.

49. A direct organic fuel cell as defined by claim 48 wherein said
contact angle is 0°.

50. A direct organic fuel cell as defined by claim 48 wherein said
carbon cloth modified surface includes a plurality of CO and COOH groups.